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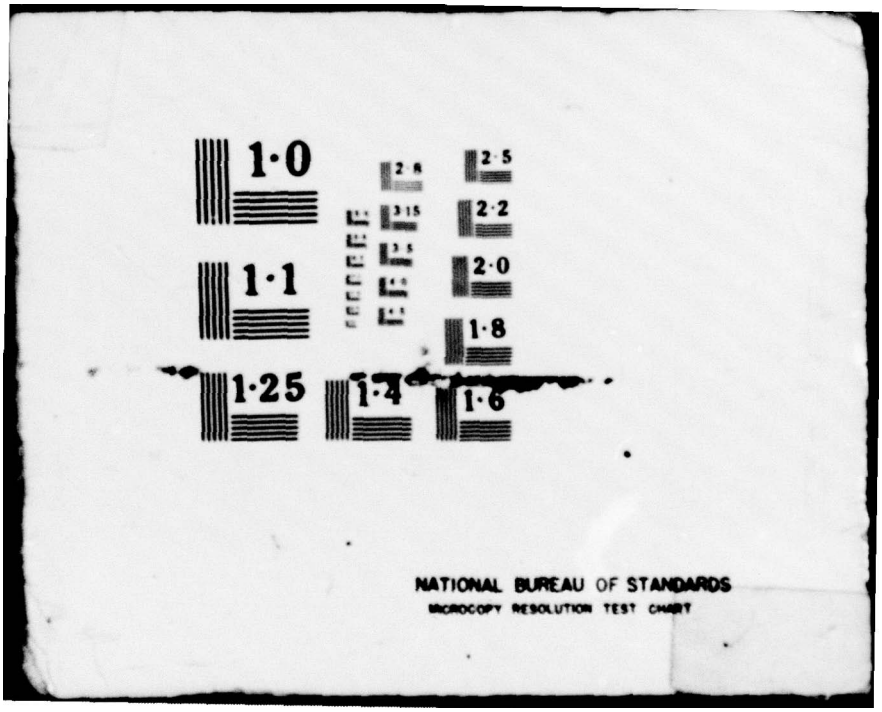
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# A MEANS OF SPECIFYING A STANDARD REFERENCE WET SURFACE FOR MILITARY AIRCRAFT

R W SUGG

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# (6) A MEANS OF SPECIFYING A STANDARD REFERENCE WET SURFACE FOR MILITARY AIRCRAFT.

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SUMMARY

Aircraft specifications which quote stop distances under dry conditions can be misleading since it is the wet case which gives the longer stop distance and may define the length of an operational runway. Trials have shown however, that the wet stop distance can be between 10% and over 100% longer than the dry distance depending on factors such as water depth and surface type. To try and overcome this problem, this paper studies the BCAR method of aircraft certification under wet conditions and the correction of stop distances to a 'standard' using a friction trailer. It concludes there is merit in this well tried method but the 'standard' is unsuitable for military aircraft and the friction trailer should be of the type in service with the RAF. In addition the 'standard' should be related to accident investigation procedures and NATO standards.

Using the BCAR method as a basis, this paper proposes a Standard Military Reference Wet Surface and a way of correcting aircraft performance to the 'standard'.

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## CONTENTS


| | | |
|---|---|---|
| 1. | Introduction | 1 |
| 2. | The BCAR Standard Reference Wet Surface | 1 |
| 3. | The Standard Military Reference Wet Surface | 2 |
| 4. | Conclusions | 3 |
| 5. | Recommendations | 3 |
| | References | 4 |


## TABLES


1. NATO Stanag 3634 - Braking Code and Conversion Table


## FIGURES


1. BCAR Standard Reference Wet Surface with average TRRL trailer runway speed/friction curves with plain tyres from trials on four runways.

2. Friction readings of Mu-Meter against TRRL trailer.

3. Comparison of BCAR Standard Reference Wet Surface with high friction surfaces, using TRRL locked wheel trailer.

4. Prediction of Mu-Meter readings at high speed from values at 40 mph under 'bowser wetting' conditions from Ref 4.

5. Typical Mu-Meter reading versus elapsed time after runway bowser wetting.

6. Trial results to establish Mu-Meter speed/friction curve at Hurn.

7. Hurn speed/friction curve with extrapolation, compared with the Standard Military Reference Wet Surface.

## 1. Introduction

1.1 Aircraft specifications usually contain a clause which specifies stop distance and the surface conditions under which it is to be demonstrated. These conditions have been variously quoted as either 'dry' or 'wet', and as aircraft trials have shown that the wet stop distance can be anything between 10% and 100% longer than the dry, the dry distance cannot be used to indicate the suitability of the aircraft under wet conditions.

1.2 It is the wet runway condition alone that will show aircraft designers if a high efficiency anti skid system is needed but the problem is how it can be specified. To decide if it can be adopted for use with military aircraft, this paper studies a method which has been used successfully with British civil aircraft for some years to determine a certified stop distance, Ref 1, under standard wet runway conditions.

## 2. The BCAR Standard Reference Wet Surface

2.1 The basis of the BCAR method is to produce runway friction conditions for the aircraft as near as possible to the BCAR curve in Fig 1, using a friction trailer approved by the Civil Aviation Authority - in this case the Transport and Road Research Laboratory locked wheel trailer described in Ref 2. The measured aircraft performance is then adjusted by calculation for any differences between the friction coefficient of the test surface as measured by the TRRL trailer and the Standard Reference Wet Surface as defined by BCAR.

2.2 By comparing the TRRL trailer friction readings at 40 mph with those at 20, 60 and 80 on a number of runway surfaces under closely controlled wetting conditions, it was possible to produce a family of speed/friction curves which are plotted in Fig 1 to show how they change as the surface becomes more slippery and compares them with the curve for the BCAR Standard Reference Wet Surface. The curves are representative of asphalt and brushed concrete runways, tested with water depths up to .060 inches and appear to indicate that the Standard Reference Wet Surface is not one which is wholly representative of normal runways as it has a higher friction at high speed and lower at low speed.

2.3 The curve in Fig 1 for the Standard Reference Wet Surface goes up to 180 mph whilst the maximum speed of the TRRL trailer is 80 and sometimes 100 mph which presents a problem as the latter has to be extended up to the aircraft 'brakes on' speed. Sometimes the extension is made by assuming the friction coefficient above 100 mph does not drop with speed and a horizontal line is drawn. An alternative and more scientific method would be to determine the best fit equation from 40 mph for the SRWS and assuming all TRRL trailer curves are of a similar type, to use test data up to 80 mph to calculate the best fit equations for other curves and extend these curves up to the aircraft 'brakes on' speed.

2.4 Using the 'alternative' method suggested in para. 2.3 an equation in the following form has been used to extrapolate the test data from some TRRL trailer runway trials. See Fig. 1.

$$\mu_V = \mu_\infty + 10^{\frac{V-b}{a}}$$

where $\mu_V$ is the friction coefficient at velocity V in mph. and $\mu_\infty$ is the estimated friction coefficient at infinite velocity. a and b are constants.

2.5 Calculations have shown that when two speed/friction curves cross they give the same stop distance from a speed equal to approximately 1.3 times the

speed at which they cross. So that if an aircraft has a 'brakes on' speed of 120 knots the cross over point between the TRRL trailer and BCAR curves, to give equal distances, would be 105 knots. Fig 1 shows that to cross at this speed requires a TRRL trailer friction reading at 40 mph of over .7 which trials between trailer and Mu-Meter have shown in Fig 2 to be the equivalent of a Mu-Meter reading of over .8. This is extremely high and corresponds to the values expected from a porous friction course or ¼" grooved asphalt, two of the highest friction surfaces used on runways.

2.6 Further confirmation of the high friction characteristics of the BCAR Standard Reference Wet Surface is provided by data from trials on a porous friction course and a harsh textured surface named Quartzite. A comparison between the friction of these surfaces and the BCAR friction curve is at Fig 3.

## 3. The Standard Military Reference Wet Surface

3.1 The BCAR Standard Reference Wet Surface appears to be one with high friction which will not provide an adequate test for braking systems and anti skid units. For military aircraft a Mu-Meter( see Ref 3) speed/friction curve should be used which represents a surface on the border of . 'medium/good' as defined in the Braking Code and Conversion Table of STANAG 3634 - Runway Braking Action ( Table 1 ) It is suggested that a Mu-Meter 40 mph reading of .55 and its related speed/friction curve derived from Fig 4, be used as the Standard Military Reference Wet Curve with an equation of:

$$\mu_v = .2 + 10^{\frac{V + 13}{-117}}$$

Experience has shown that it is difficult to create a more slippery runway surface by the artificial wetting procedure used during aircraft trials.

3.2 Briefly the test procedure is to wet a selected portion of the runway using water bowsers and to run the Mu-Meter along the same track both before and after landing the aircraft and by using a time base as in Fig 5, determine the reading at the time of the aircraft landing. Since it is probable that, due to practical difficulties, the Mu-Meter reading at the time of touchdown will not be .55 a correction method must be devised.

3.3 Provided the Mu-Meter reading during the aircraft test is within the band .5 to .6, then a proportioned correction to the aircraft speed/friction curve can be used. By comparing the Mu-Meter reading at 40 mph, obtained during the test,with Fig 4, the corresponding readings at speeds up to 140 mph can be obtained. The aircraft speed/friction curve can then be corrected in direct proportion to the difference in readings on the two Mu-Meter curves. The aircraft stop distance which can then be calculated will be that on the Standard Military Wet Reference Surface.

3.4 An alternative method of determining the Mu-Meter speed/friction curve at the time of the aircraft run, is to wet the test surface at some convenient time not associated with the aircraft trial and make runs at 20, 40, 60 and 80 mph whilst the surface is drying out. By timing each run it is then possible to plot a grid of Mu-Meter readings versus time and speed as in Fig 6. Using the 40 mph reading corresponding to the time of the aircraft test run (see Fig 5) the speed/friction curve up to 80 mph can be determined and extrapolated to higher speeds by calculating the best fit equation as shown in Fig 7, where it is compared with the Standard Military Reference Wet Surface.

3.5 The limits of .5 to .6 within which a proportional correction can be applied has been set arbitrarily. Provided it has been established before the trial that, with the wetting equipment available, it is possible to get Mu-Meter values below .55. by making a series of Mu Meter runs as in Fig. 5, the approximate time can be determined for the runway to reach the correct test condition. This time can then be used during the aircraft trial

3.6 There will be occasions when a lack of detail knowledge of thrust, lift and drag makes it impossible to calculate aircraft friction coefficient against speed. Provided the test runway conditions are very close to that specified for the Standard Military Reference Wet Surface ie $\pm$ .03 then the deceleration/speed curve can be used since any errors in the proportioning process caused by their omission, will be negligible.

## 4. Conclusions

4.1 Tests with the TRRL locked wheel trailer appear to indicate the friction/speed curve for the BCAR Standard Reference Wet Surface defines one with high friction which gives a Diagonal Braked Vehicle wet to dry stop distance ratio of 1.2. This is too high to demonstrate the capabilities of anti skid systems. (Para 2.5 and 2.6).

4.2 A Mu-Meter reading of .55 at 40 mph should be used to specify a Standard Military Reference Wet Surface (Para 3.1).

4.3 Methods of correcting aircraft stop distances to the Standard Military Reference Wet Surface described in paras. 3.3, 3.4, 3.5 and 3.6 should be adopted.

## 5. Recommendations

5.1 Aircraft stop distances should always be specified under wet conditions.

5.2 The Standard Military Reference Wet Surface and its method of definition should be used as a standard for aircraft specification purposes.

5.3 The method described in this paper be used to correct aircraft stop distance data to the Standard.

Table 1

NATO STANAG 3634 BRAKING CODE AND CONVERSION TABLE

| Braking Code | Mu-Meter Reading | Verbal Description |
|---|---|---|
| A | .5 and above | Good |
| B | .49 to .35 | Medium |
| C | .34 and below | Poor |

## REFERENCES


1. British Civil Airworthiness Requirements.

2. R.F.A.Judge "A Note on Aquaplaning and Surface Treatments to improve the skid resistance of airfield pavements - MPBW October 1965.

3. Continuous Recording Runway Friction Meter - Air Publication AP 119J - 1001 - 126A.

4. R W Sugg - An investigation into the use of measuring runway surface texture by the grease patch and Outflow Meter methods - S and T Memo 2/79

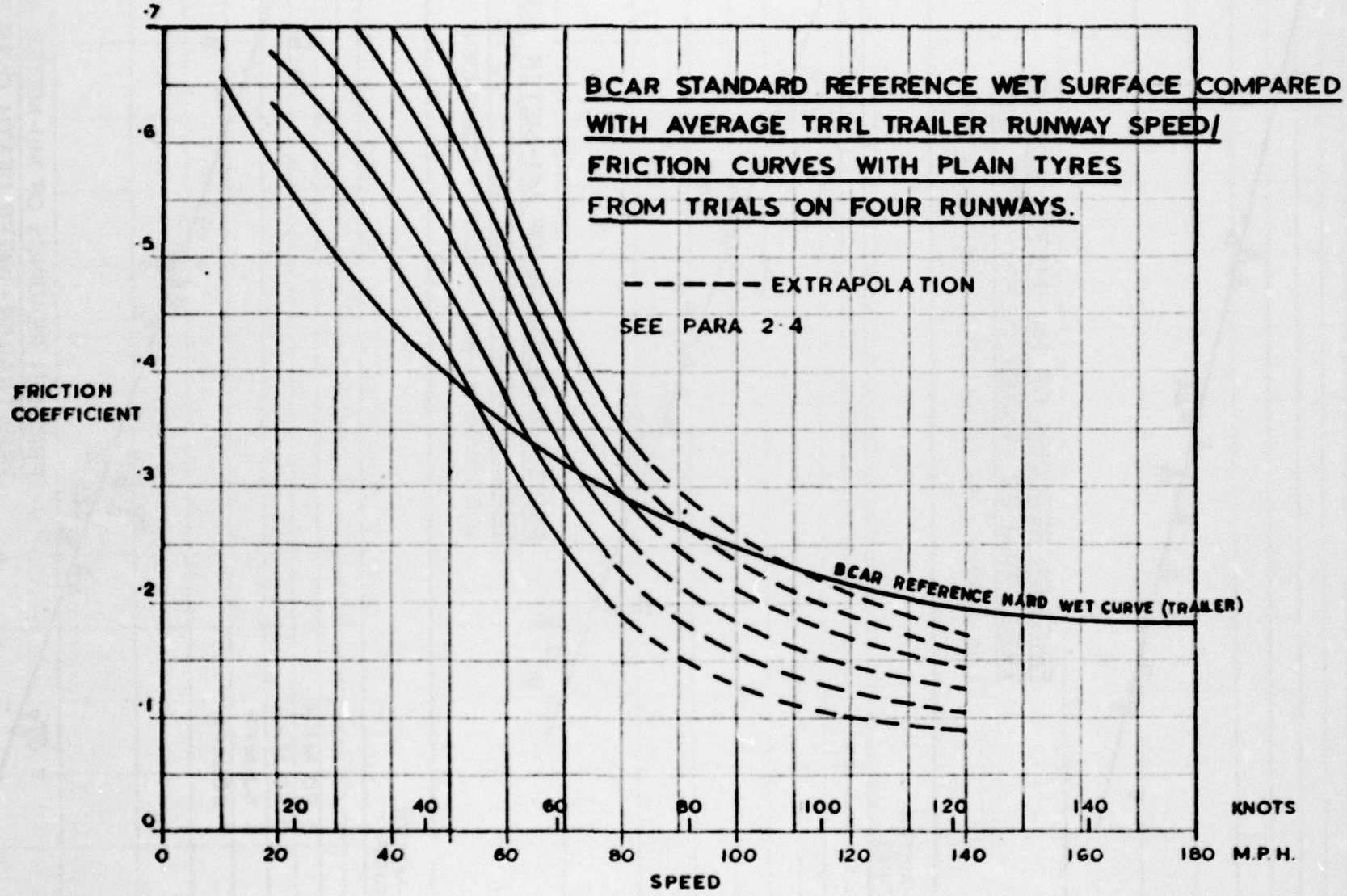
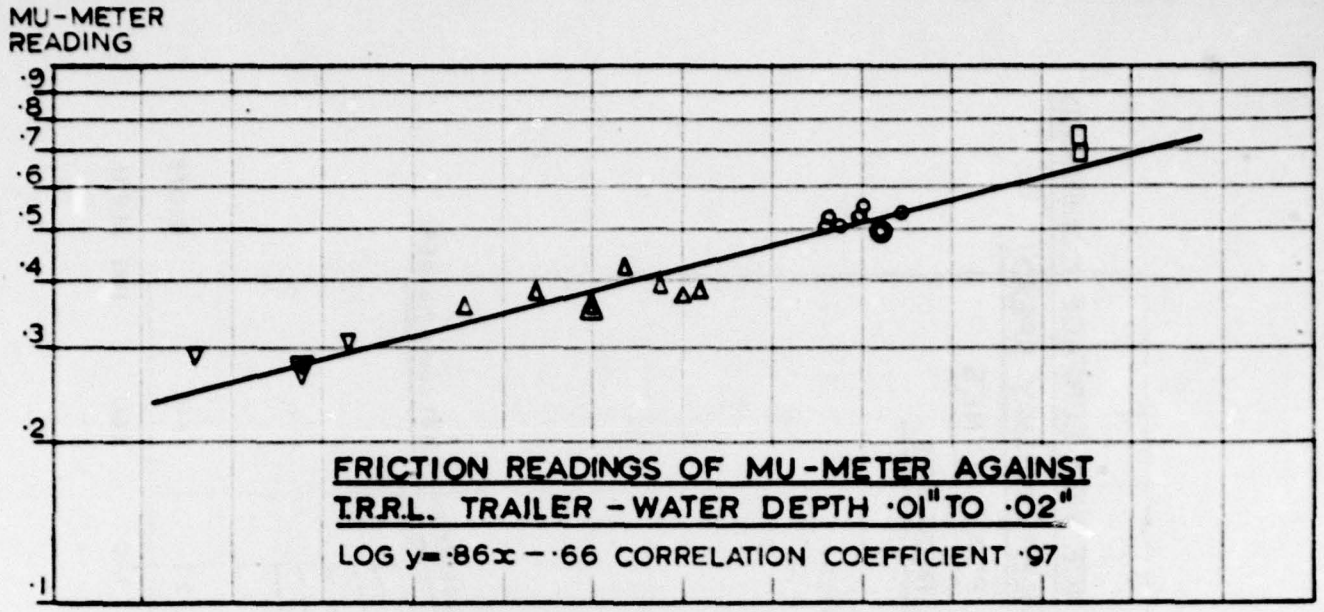
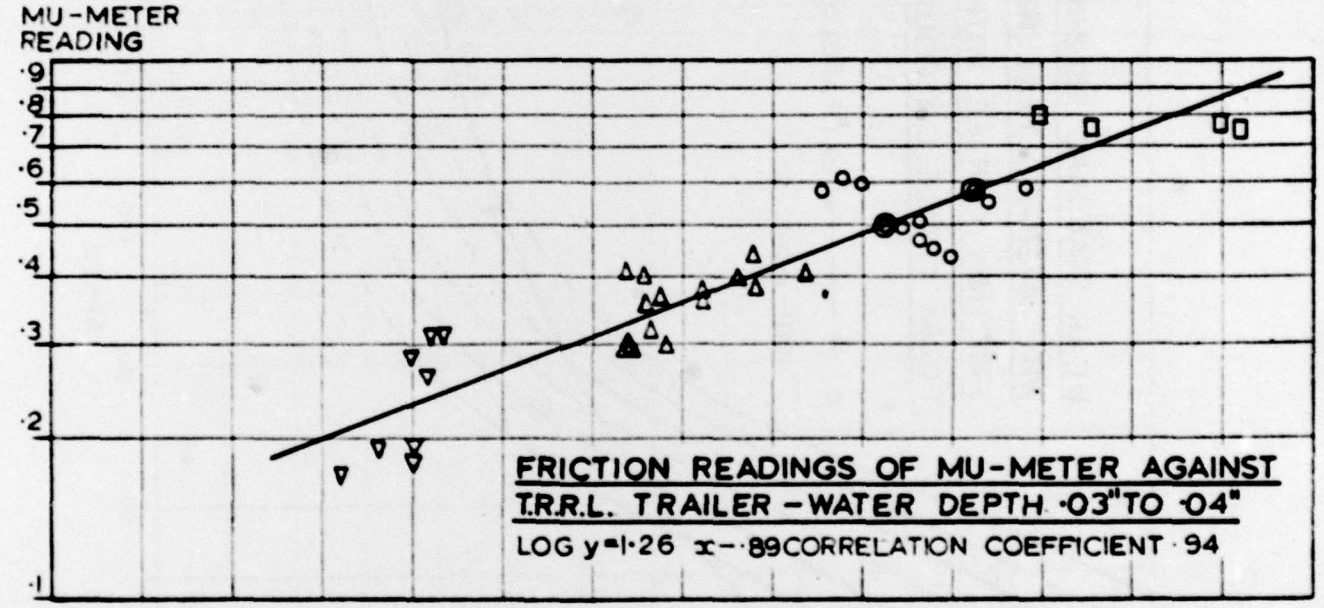

BCAR STANDARD REFERENCE WET SURFACE COMPARED WITH AVERAGE TRRL TRAILER RUNWAY SPEED/ FRICTION CURVES WITH PLAIN TYRES FROM TRIALS ON FOUR RUNWAYS.
EXTRAPOLATION
SEE PARA 2·4
BCAR REFERENCE HARD WET CURVE (TRAILER)
FRICTION COEFFICIENT
·7
·6
·5
·4
·3
·2
·1
0
0 20 40 60 80 100 120 140 160 180 M.P.H.
20 40 60 80 100 120 140 KNOTS
SPEED

FIG. 1


MU-METER READING
·9
·8
·7
·6
·5
·4
·3
·2
·1
FRICTION READINGS OF MU-METER AGAINST T.R.R.L. TRAILER - WATER DEPTH ·01" TO ·02"
LOG y = ·86x - ·66 CORRELATION COEFFICIENT ·97


MU-METER READING
·9
·8
·7
·6
·5
·4
·3
·2
·1
FRICTION READINGS OF MU-METER AGAINST T.R.R.L. TRAILER - WATER DEPTH ·03" TO ·04"
LOG y = 1·26 x - ·89 CORRELATION COEFFICIENT ·94

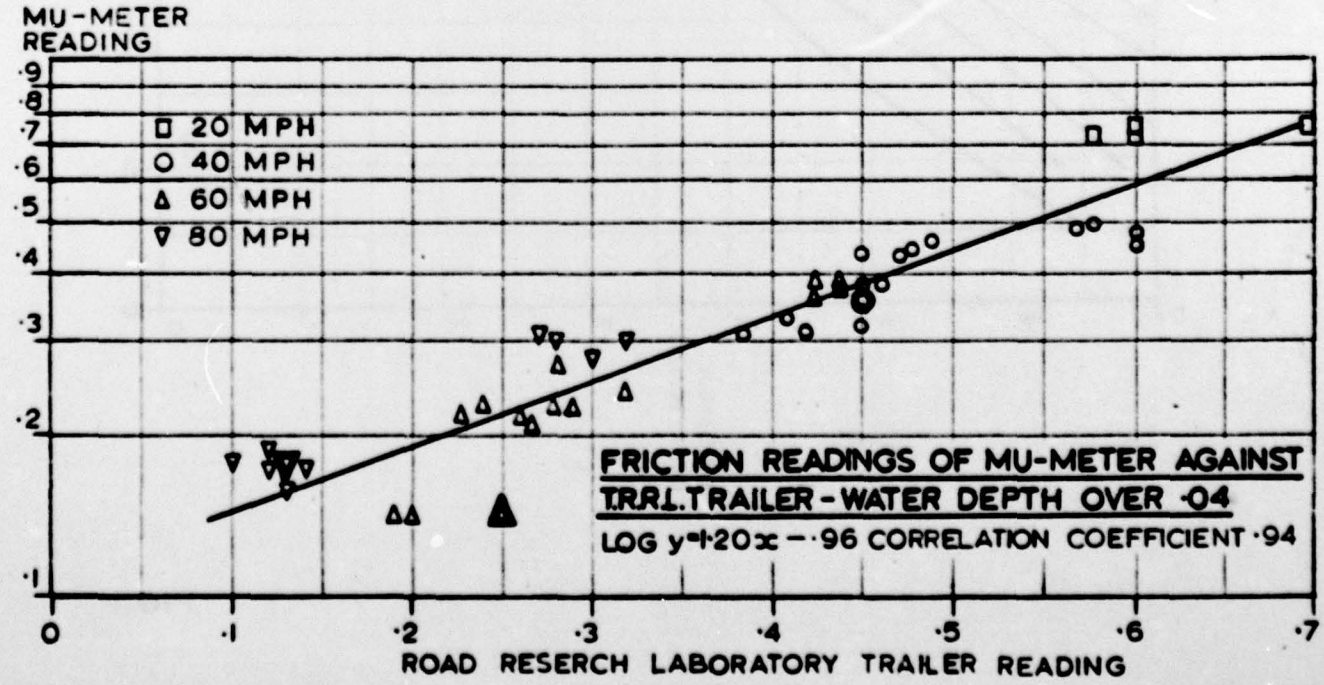

MU-METER READING
·9
·8
·7
·6
·5
·4
·3
·2
·1
20 MPH
40 MPH
60 MPH
80 MPH
FRICTION READINGS OF MU-METER AGAINST T.R.R.L. TRAILER - WATER DEPTH OVER ·04
LOG y = 1·20x - ·96 CORRELATION COEFFICIENT ·94
0
·1
·2
·3
·4
·5
·6
·7
ROAD RESERCH LABORATORY TRAILER READING

FIG. 2

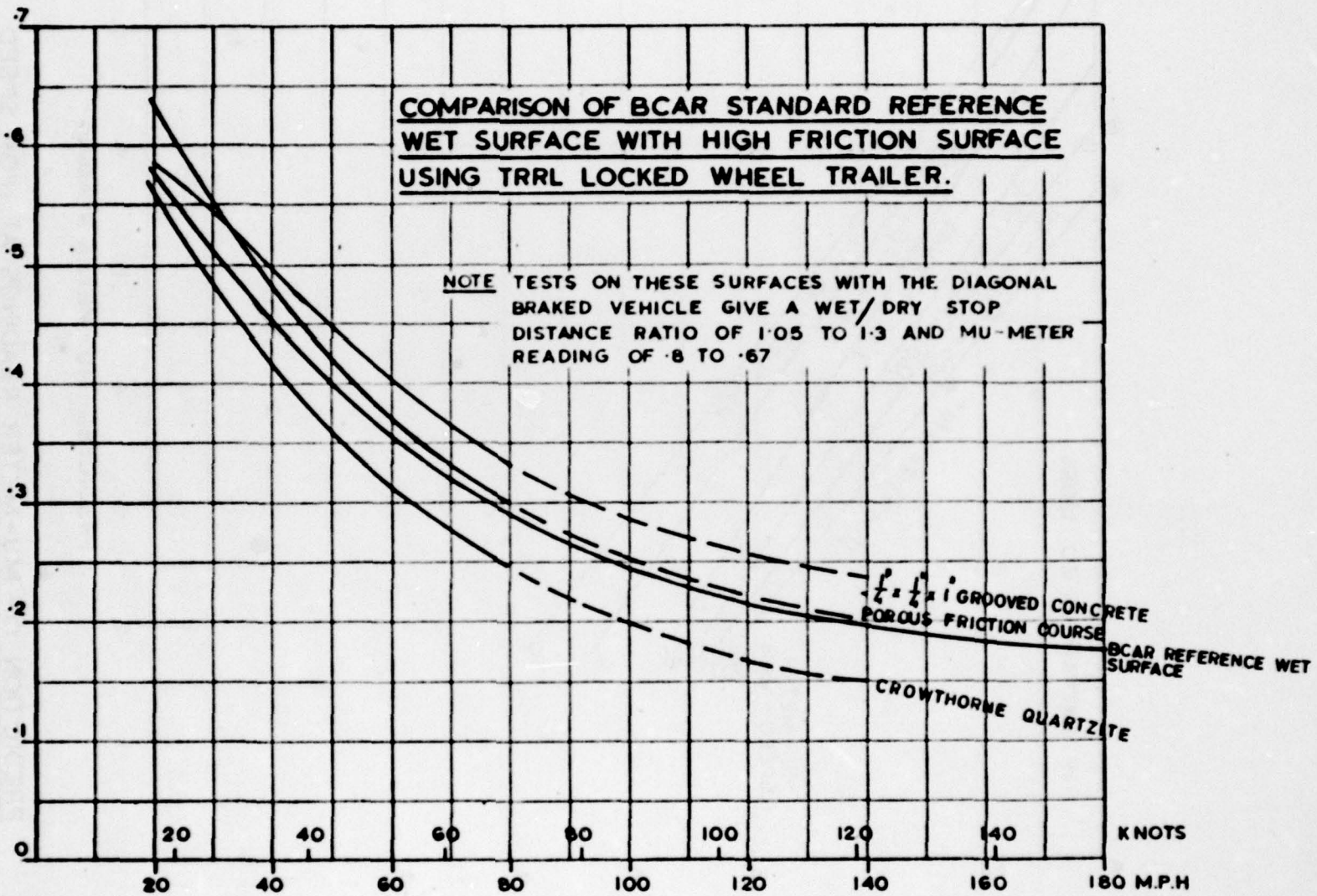
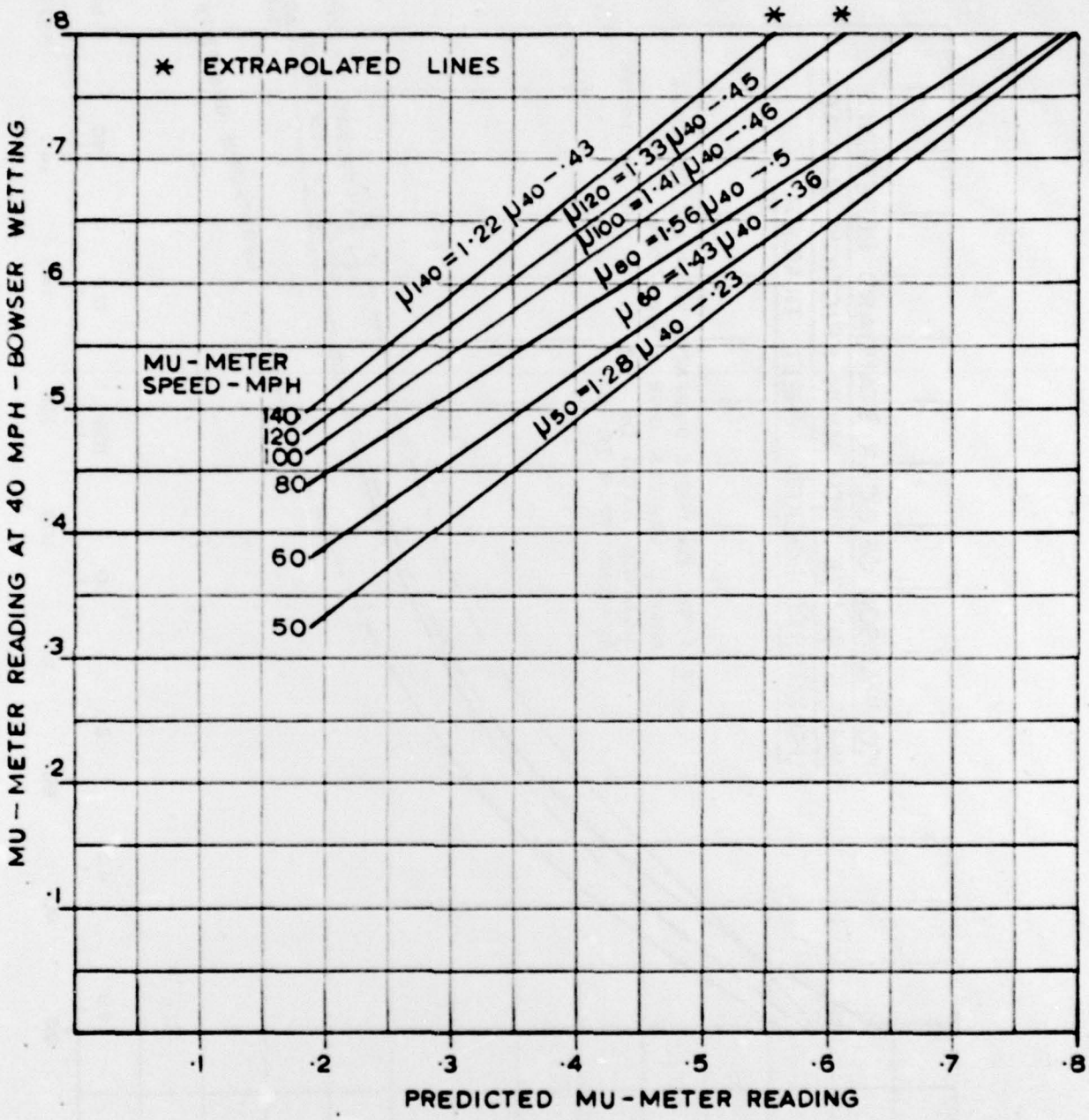
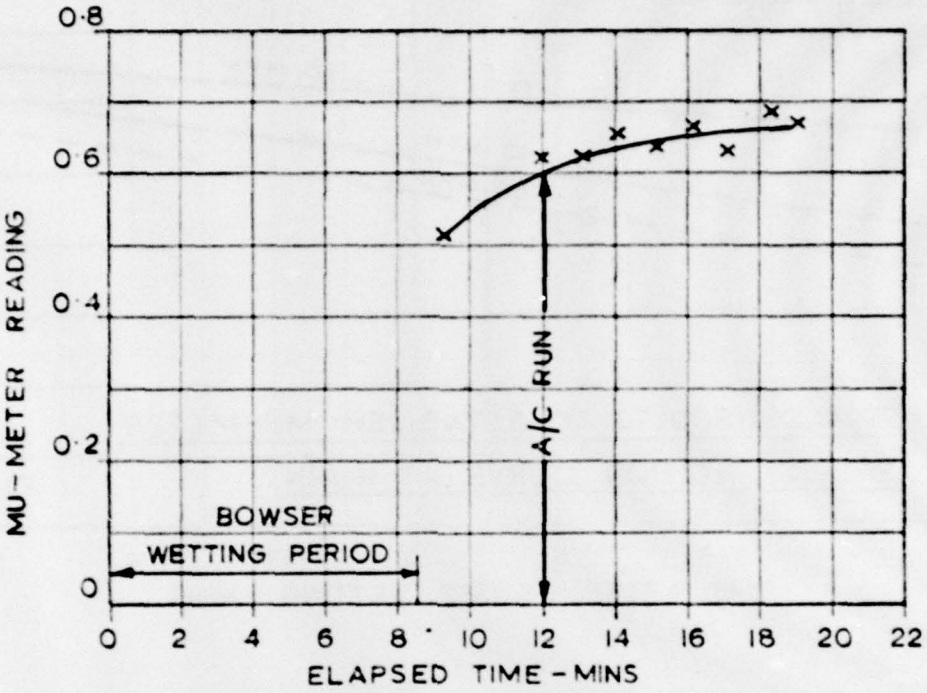

COMPARISON OF BCAR STANDARD REFERENCE WET SURFACE WITH HIGH FRICTION SURFACE USING TRRL LOCKED WHEEL TRAILER.
NOTE TESTS ON THESE SURFACES WITH THE DIAGONAL BRAKED VEHICLE GIVE A WET/DRY STOP DISTANCE RATIO OF 1·05 TO 1·3 AND MU-METER READING OF ·8 TO ·67
μ
·7
·6
·5
·4
·3
·2
·1
0
GROOVED CONCRETE
POROUS FRICTION COURSE
BCAR REFERENCE WET SURFACE
CROWTHORNE QUARTZITE
20
40
60
80
100
120
140
KNOTS
20
40
60
80
100
120
140
160
180 M.P.H

FIG. 3



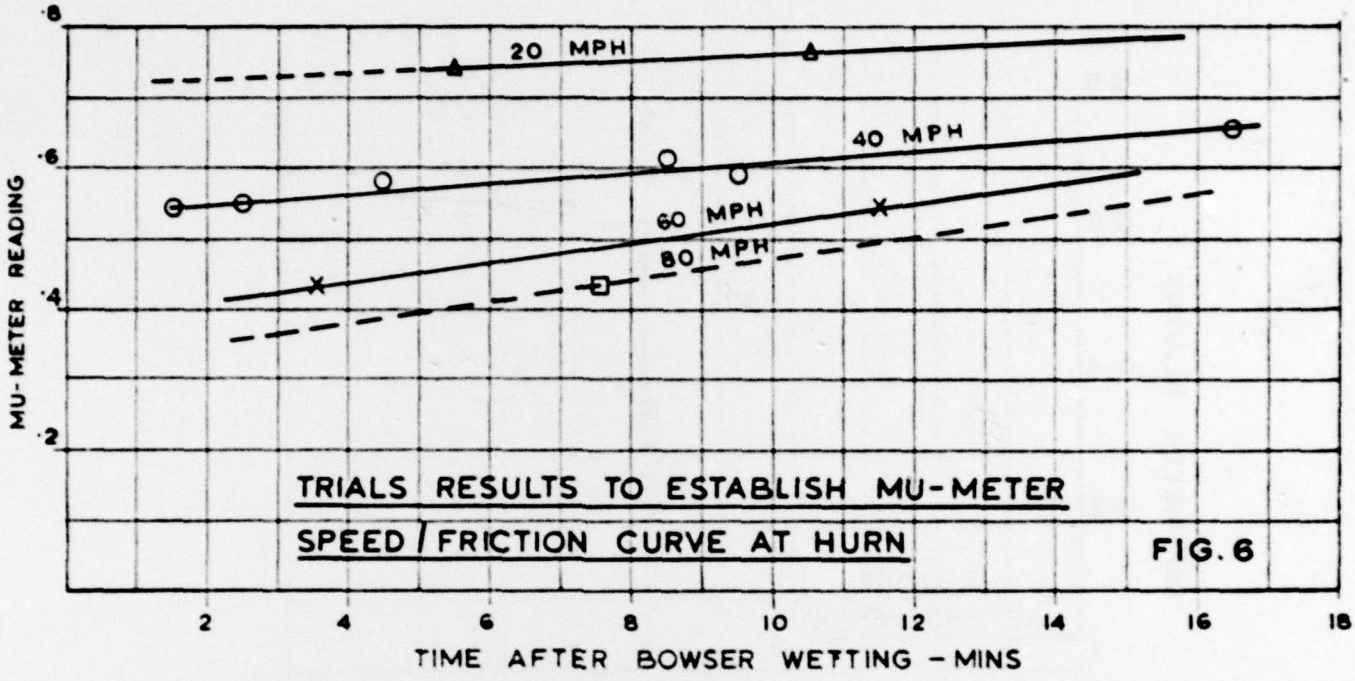

**PREDICTION OF MU-METER READINGS AT HIGH SPEED FROM VALUES AT 40 MPH UNDER BOWSER WETTING FROM REF 4**

FIG. 4




**TYPICAL MU-METER READING VERSUS ELAPSED TIME AFTER RUNWAY BOWSER WETTING**

FIG. 5




TRIALS RESULTS TO ESTABLISH MU-METER SPEED / FRICTION CURVE AT HURN

FIG. 6

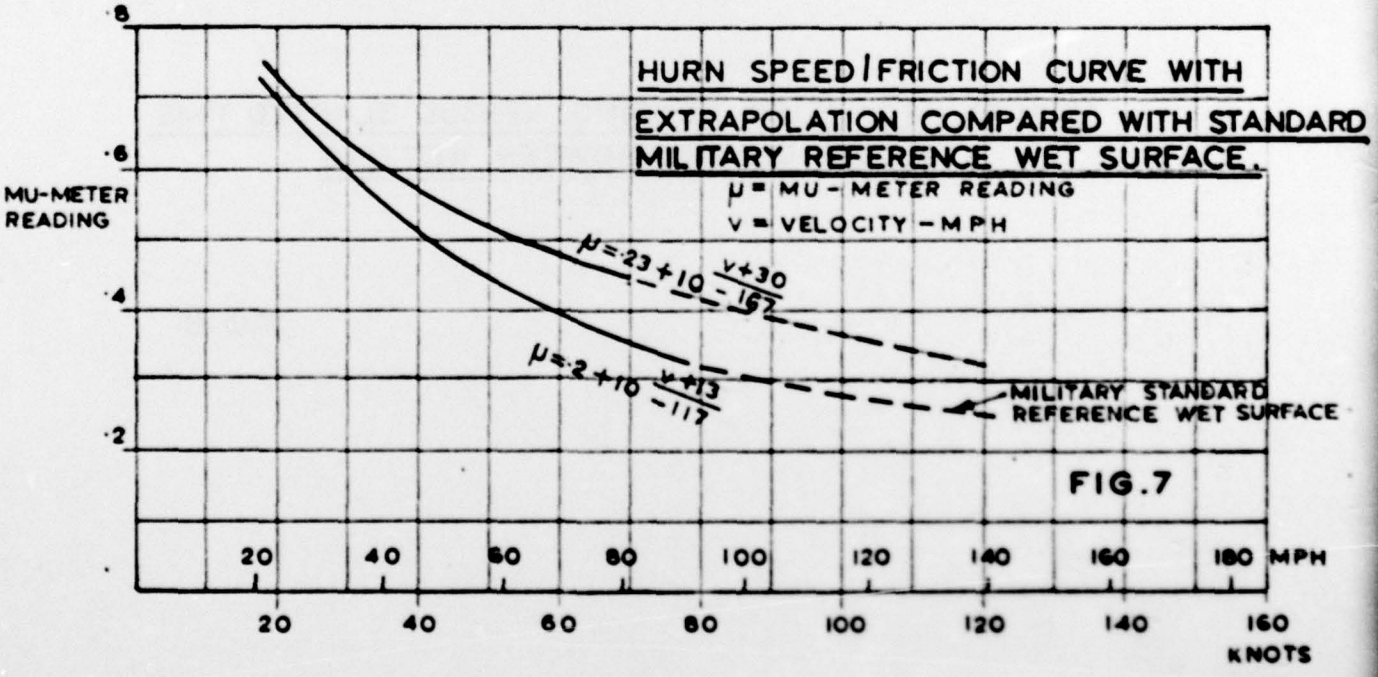



FIG. 7

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| Sugg, R.W. | | | 10.1979 | 13 | 4 |

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Abstract Aircraft specifications which quote stop distances under dry conditions can be misleading since it is the wet case which gives the longer stop distance and may define the length of an operational runway. Trials have shown however, that the wet stop distance can be between 10% and over 100% longer than the dry distance depending on factors such as water/depth and surface type. To try and overcome this problem, this paper studies the BCAR method of aircraft certification under wet conditions and the correction of stop distances to a 'standard' using a friction trailer. It concludes there is merit in this well tried method but the 'standard' is unsuitable for military aircraft and the friction trailer should be of the type in service with the RAF. In addition the 'standard' should be related to accident investigation procedures and NATO standards. Using the BCAR method as a basis, this paper proposes a Standard Military Reference Wet Surface and a way of correcting aircraft performance to the 'standard'.

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